Punch Load of Non-Axisymmetric Deep Drawing Product According to Blank Shape

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Abstract
Deep drawing process, because of its efficiency is very much sought in sheet metal forming industries. The production of optimal products using this process is dependent on the process variables such as blank shapes, profile radii of punch and die and formability of the material. Out of these variables, blank shape is very important since it controls the formability factor. This paper reports the investigations on three kinds of blank shapes and the friction test on these three conditions. The punch load distributions for non-axisymmetric forming processes were measured under different conditions of profile radii of punch and die and discussed here.

Key Words:
Deep drawing, Blank shapes, Friction test, Punch load

1. INTRODUCTION

The sheet metal forming processes have an important role in industries such as automobile, aeronautical and electric appliance due to their reduced development time and low cost. This process involves either one or a combination of stretching, drawing and repetition of bending and unbending. Many studies have been carried out on the process variables of deep drawing for producing cylindrical, rectangular, elliptical and non-axisymmetrical shapes. Most of the research work in deep drawing is directed towards the formability of axisymmetrical shapes. There have been very few reports on the formability of non-axisymmetric shapes.

For determining the drawabilty of a non-axisymmetrical product, various process variables such as material property, profile radii of punch and die, lubrication condition, ram speed, blank holding force, clearance etc must be considered. The profile radii of the punch and die and blank shape are the important variables since these can influence the formability of the process [1-4]. If appropriate profile radii of the punch and die and blank shape can be selected, then the lead time and cost of the product can be reduced [5, 6].

2. DEEP DRAWING EXPERIMENT

2.1. Materials

The material used in this study was SECD (Korean Standards) with high quality formability and a thickness of 1.6 ㎜. Specimens were galvanized with Zinc of 20 ㎛. Tensile tests were carried out in the directions of 0°, 45°, and 90°to the rolling direction. The gauge length and width of the tensile specimens were 25 and 50 ㎜ respectively. The mechanical properties of the material in the tensile direction are indicated in Table 1. The specimens for the tensile tests were cut by a wire-electric spark machine. The tensile strength of the specimens was measured by the tensile test using UTM with setting load speed as 10 ㎜/min.

2.2. Equipment and Conditions

Fig. 1 shows the equipment used hydraulic press (100 Ton) with a die-cushion to control blank holding force and limit switch to determine a stroke of upper ram according to the processes. A computer with a linear variable differential transformer (LVDT) was used to measure the punch load with respect to the punch stroke when the steel sheet was formed.

Table 2 shows the experimental conditions for profile radii of the punch and die. The punch profile radius (R_p) was fixed on 6.4 ㎜, the die profile radius (R_d) was selected based on two different conditions. The punch stroke for the experiment consists of three strokes which are (a) 46 ㎜ in the first process; (b) 62 ㎜ in the second process; and (c) 74 ㎜ in the third process. The blank holding pressure was fixed at 2N/㎟. Soluble oil was used as lubricant for plastic working.

Table 1: Mechanical properties in the tensile direction

Direction	Yield strength [MPa]	Tensile strength [MPa]	Elongation [%]
0^o	182	426	48.4
45^o	200	433	41.4
90^o	205	412	48.2
Average	195.7	423.7	46

Fig. 1: Experimental equipment for deep drawing

2.3. Friction Test

The friction test was divided conditions into three types, non lubrication, full lubrication, and film lubrication. This was to obtain mean the friction coefficient according to the pin load [7]. Table 3 shows the mean friction coefficient of each condition. This consists of a load cell that could measure the friction coefficient, personal computer that calculates and saves the measured signal, and a pneumatic cylinder that transforms the energy of compressed air into a mechanically reciprocating straight line motion.

Table 2: The experimental conditions for punch and die Profile radii

	First Process R_{d1} [㎜]	Second Process R_{d2} [㎜]	Third Process R_{d3} [㎜]
Blank type (A, B, C)	11.2	11.2	11.2
			16
		16	11.2
			16
	16	11.2	11.2
			16
		16	11.2
			16

Table 3: Mean friction coefficient of each test

Type	150N	200N	250N	Mean value
Non lubrication	0.24	0.26	-	0.25
Full lubrication	0.08	0.15	-	0.12
Film lubrication	0.09	0.07	0.08	0.08

3. BLANK SHAPE DESIGN

Generally, the trial-and-error method based on previous experience is used for developing the blank shape. This will increase the production time and cost. Hence, to design the blank shape (which is equivalent to the surface area of the final product) the surface area of the final product was determined by means of 3D modelling [8-12]. Three kinds of blanks, which have an equivalent surface area to the final product, were used. Fig. 3 shows the geometrical shapes of the blanks used. The outline of the type A blank is larger than the type B and C blanks. The short side length of the type B blank is smaller than the type C blank. On the contrary, the long side length of the type B blank is a little larger than the type C blank. The process of the applied product in the experiment consists of 7 stages of the deep drawing process and 3 stages of trimming and restriking.. Hence, the total number of multi-deep drawing stages is 10. In this study, the experiment to measure punch load was performed from the first process to the third process. Fig. 4 shows the product shape of each type blank according to process.

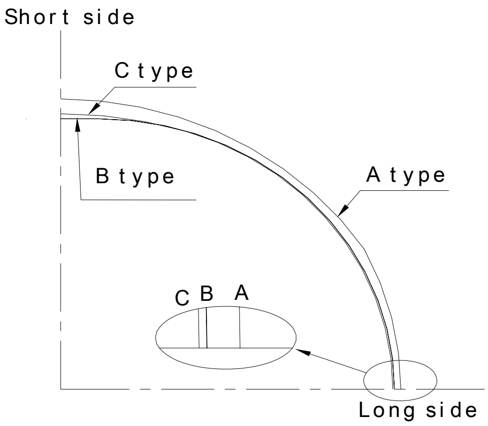

Fig. 3: Geometry of blank shapes

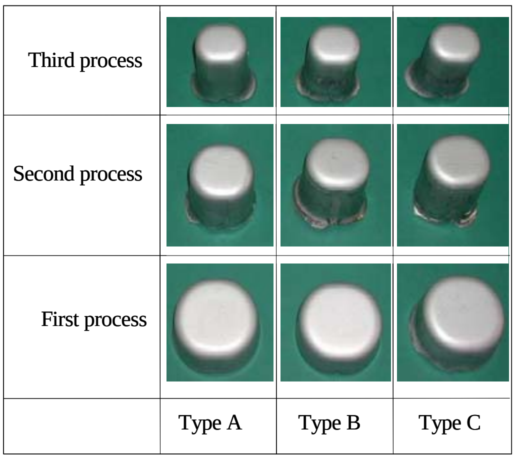

Fig. 4: Product shapes of each type blank

4. RESULT AND DISCUSSIONS

Fig. 5 and Fig. 6 show the comparison of the punch load along the blank types in the first process. R_p was fixed at 6.4 ㎜, R_{d1} of the first process was selected under two conditions, such as 11.2 ㎜ and 16 ㎜. The punch load of the type A blank measured relatively large in comparison with the type B and C blanks, and the punch loads of the type B and C blanks were similar. The area of the type A blank is on the whole large in comparison with the type B and C blanks. In other words, the contact surface area of blank holder of the type A blank is larger than that of the type B and C blanks. Therefore, it is considered that the largest value of the punch load is measured at the type A blank where the high blank holding force is needed due to the large contact surface area of the blank holder. Table 4 shows the maximum punch load of the blank shapes along the die profile radii in the first process. The maximum punch load when R_{d1}=16 ㎜ is smaller than when it is R_{d1}=11.2 ㎜.

Table 4: The Max. punch load of blank shapes in the first process (R_p=6.4)

	Type A	Type B	Type C
Max. Punch load (ton)	R_{d1}=11.2 : 13.1	R_{d1}=11.2 : 10.9	R_{d1}=11.2 : 11.4
	R_{d1}=16 : 11.2	R_{d1}=16 : 9.8	R_{d1}=16 : 9.9

Fig. 7 and Fig. 8 show the comparison of the punch load along the blank types in the second process. R_p was fixed at 6.4 ㎜, the die profile radius of the first process (R_{d1}) was fixed at 16 ㎜ and the die profile radius of the second process (R_{d2}) was selected under two conditions, such as 11.2 ㎜ and 16 ㎜. The maximum punch load was measured at 80 percent of punch stroke when the type A, B blanks were used, and was measured at 60 percent of punch stroke when the type C blank was used. The punch load in each process was compared and it is seen that the punch load of the second process was smaller than the first process and the results of experiments showed that the punch load of the three types of blanks was similar. The punch load is small while the blank draws from the first to the second process due to the reduced drawing length.

R_p was fixed at 6.4 ㎜, compared the two conditions, the one, R_d of the first, second and third process was fixed at 16 ㎜, the other die profile radii (R_{d1}) of the first, second and third process was fixed at 11.2 ㎜.

The punch load of the type A blank was relatively large in comparison with the type B and C blanks while the punch stroke made progress. We attributed some difference of the punch load to friction between the punch and the steel sheet. If the maximum punch load is larger than the fracture force (P_F) to shear the steel sheet when forming a non-axisymmetric product, then the fracture will occur at that time. Theoretically P_F is calculated as follows.

$$P_F = Lt\sigma_b = 210 \times 1.6 \times 43.29$$

The fracture force (P_F) was calculated using the drawing length (L) of the blanks. It is 14.5ton. Therefore, the maximum punch load measured in the experiments, 13.1ton, was performed without the fracture of the non-axisymmetric product.

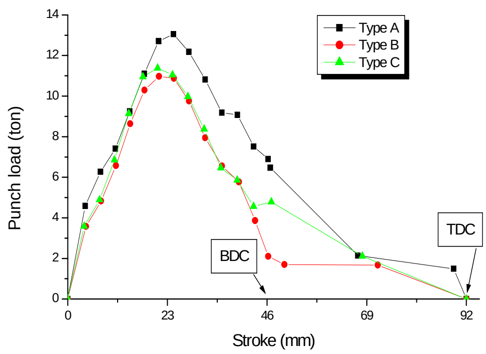

Fig. 5: Punch load-stroke curve of each blank type (R_{d1}=11.2 ㎜)

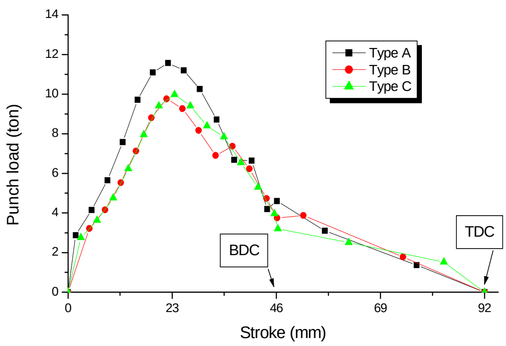

Fig. 6: Punch load-stroke curve of each blank type (R_{d1}=16 ㎜)

Because the type A blank is larger than the type B and C blanks, the blank holding force has increased. Therefore, the punch load of the type A blank shows a large value in every process due to an increase in the blank holding force. In contrast to the type A blank, since the punch load of the type B and C blanks is smaller than that of the type A blank, the blank holding force was found to be decreased. Therefore, the punch load of the type B and C blanks shows a small value for every process due to the reduced blank holding force. Although the punch load is similar to that in the type B blank, a good product that has no discontinuous section could make from the type C blank. Hence it is advantageous to use type C blank in the industrial field.

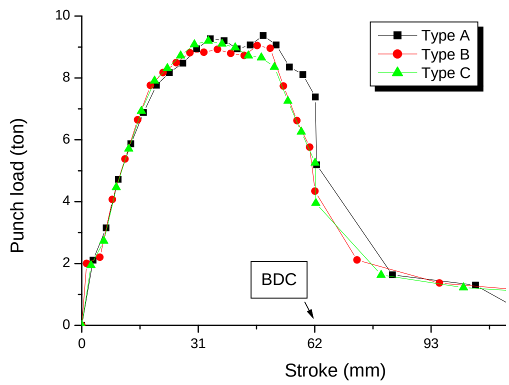

Fig. 7: Punch load-stroke curve of each blank type (R_{d1}=16 ㎜, R_{d2}=11.2 ㎜)

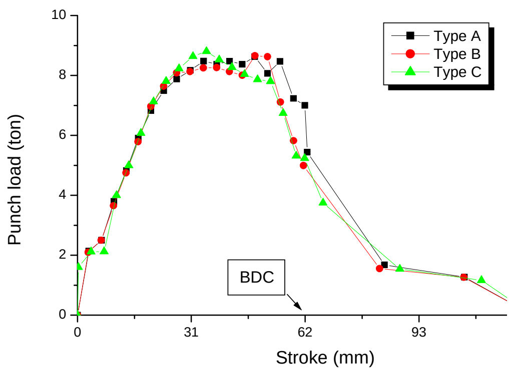

Fig. 8: Punch load-stroke curve of each blank type (R_{d1}=16 ㎜, R_{d2}=16 ㎜)

5. CONCLUSIONS

In this study, experiments were carried out for tensile and friction with steel sheets for drawability for a non-axisymmetric product. The experiments clarified the influence of the profile radii of the punch and die and the blank shape on the punch load distribution for non-axisymmetric deep drawing products. From the results the followings conclusions are drawn.

(1) Under the friction test conditions of three types, non lubrication, full lubrication, and film lubrication, the results of friction test showed that the mean friction coefficient measured the smallest value, 0.08, when film lubrication was used. Better results were obtained with the applied film lubrication to the non-axisymmetric product as compared to full lubrication.

(2) The maximum punch load was reduced gradually as the process progressed.

(3) The maximum punch load of the type A blank had the largest value among the three kinds of blanks during the process and although the type C blank's punch load is similar than that of the type B blank, good products without discontinuous section could be obtained from the type C blank.

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